Before the
FEDERAL COMMUNICATIONS COMMISSION, Washington, D.C. 20554

Federal Communications Commission		FCC 15-138
In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Service	)	GN Docket No. 14-177
	)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
	)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 to Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
	)	
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations	)	IB Docket No. 97-95

COMMENTS BY MOBILE MANUFACTURERS FORUM

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I - INTRODUCTION AND SUMMARY

The Mobile Manufacturers Forum (MMF) submits these comments in response to the Federal Communications Commission's ("FCC") Notice of Proposed Rulemaking ("NPRM") on a range of proposals to facilitate fifth generation ('5G") mobile communications utilizing millimeter wave ("mmW") bands. The MMF is an international association of telecommunications equipment manufacturers with an interest in mobile or wireless communications, including the manufacturers of mobile handsets and devices as well as the manufacturers of the network infrastructure. Established to support research into the health and safety of radio frequency electromagnetic fields, the MMF has worked with national and international health agencies to support identified research and with international standards setting organizations on compliance related standards. Further information on the MMF can be found on our website at www.mmfai.org.

The Commission has clearly recognised in the proceeding that spectrum is a scarce resource and the interest in utilizing frequency bands above 6 GHz for future radio communication systems is increasing. The MMF supports the Commission's proposals to allow the use of higher frequency bands for radio communication systems particularly for 5th generation ('5G') networks and devices. However, as the Commission has also acknowledged these higher frequency bands imply new challenges in terms of electromagnetic field ('EMF') exposure assessment since the fundamental exposure metrics (basic restrictions) are changing from Specific Absorption Rate ('SAR') to power density ('PD').

In this submission the MMF submits that (1) when one reviews the current PD limits from the FCC, ICNIRP and IEEE – the better basis for the limits in the range being considered by the Commission would be those from IEEE C95.1 (C95.1-2005 and C95.1a-2010); (2) that at the transition frequency where the exposure metric changes from SAR to PD, to ensure compliance with current FCC EMF exposure limits for a device used in close proximity to the body, a discontinuity of several dB has been reported in the literature[1], such that the estimated maximum output power in uplink for such devices would be limited to 15 dBm for single-element dipole antennas and much less for antenna arrays, thus placing a real constraint on network capacity and coverage; and (3) in order to be able to realise the potential of 5G, manufacturers require greater clarity from the Commission as to the measurement and assessment methodologies that can be or are to be used for demonstrating compliance with the relevant limits.

[1] D. Colombi, B. Thors, and C. Tornevik, "Implications of EMF Exposure Limits on Output Power Levels for 5G Devices above 6 GHz," IEEE Antennas and Wireless Propagation Letters, vol. PP, no. 99, pp.1, Feb. 2015.

II - NOTICE OF PROPOSED RULEMAKING

(A) The differences between ICNIRP, IEEE and FCC limits above 10 GHz suggest that the limits need to be updated.

The basic restrictions in power density, as provided by the major international standards setting organisations ICNIRP[2] and IEEE (C95.1-2005[3] and C95.1a-2010[4]) as well as for the FCC for general public exposure, are presented in Table 1. ICNIRP specifies basic restrictions in terms of power density starting from 10 GHz and the limit value is intended to be spatially averaged over an area of 20 cm^2; in addition, the spatial maximum PD averaged over 1 cm^2 should not exceed 20 times the given limit. For frequencies above 6 GHz, the FCC currently specifies a spatial peak PD of 10 W/m^2 for the general public. In IEEE C95.1-2005 PD basic restrictions are specified starting at just 3 GHz. These are intended to be spatially averaged values over an area of $100\lambda^2$ for frequencies below 30 GHz and over 100 cm^2 for frequencies above 30 GHz. The peak PD limit in IEEE C95.1 is $18.56f^{0.699}$ for frequencies between 3 GHz and 30 GHz (where f is the frequency in GHz). Above 30 GHz, the peak power density in IEEE C95.1 is 200 W/m^2.

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[2] "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", International Commission on Non-Ionizing Radiation Protection (ICNIRP), Health Physics, vol. 74, pp 494-522, April 1998.

[3] IEEE C95.1- 2005, "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, April 2006.

[4] IEEE C95.1a- 2010, Amendment 1: Specifies Ceiling Limits for Induced and Contact Current, Clarifies Distinctions between Localized Exposure and Spatial Peak Power Density", March 2010.

Table 1 EMF power density basic restrictions as provided in ICNIRP, FCC and IEEE C95.1-2005 and C95.1a-2010 for general public exposure.

ICNIRP	FCC	IEEE C 95.1 – 2005 + IEEE C 95.1 – 2010a	
$f \geq 10$ GHz	$f \geq 6$ GHz	3 GHz $\leq f \leq$ 30 GHz	$f \geq 30$ GHz
10 W/m^2 (averaged over 20 cm^2)	10 W/m^2 (spatial peak)	10 W/m^2 (averaged over 100λ^2)	10 W/m^2 (averaged over 100 cm^2)
200 W/m^2 (averaged over 1 cm^2)	–	$18.56f^{0.699}$ (spatial peak)	200 W/m^2 (spatial peak)

The lack of consensus among the different standards indicates that further research is needed to define accurate limits at these frequency bands. In part this lack of consensus can be attributed to the age of the respective recommendations. The MMF notes that while the Commission has an open proceeding that is examining its RF exposure rules and policies ('RF Inquiry')[5], the fact that the scientific basis of the current FCC exposure limits is 25 years old being based on ANSI/IEEE C95.1-1992 Standard[6] and the NCRP's 1986 report on Biological Effects of RF Fields[7], suggests that it is definitely time to update the limits in view of contemporary scientific knowledge.

It is also of note that a recent published paper[8] has questioned the current limits at the higher frequencies, since they appear to be designed with extremely large safety margins - much larger than those adopted for the basic restrictions at lower frequencies and considering that at these frequencies the absorption is

[5] See Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies; Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields, ET Docket Nos. 13-84, 03-137, First Report and Order (RF Order) and Further Notice of Proposed Rule Making (RF Further Notice) and Notice of Inquiry (RF Inquiry), 28 FCC Rcd 3498 (2013).

[6] The IEEE C95.1-1991 standard was adopted by ANSI in 1992 to become ANSI/IEEE C95.1-1992.

[7] 47 CFR 2.1093 (d), "The limits to be used for evaluation are based generally on criteria published by the American National Standards Institute (ANSI) for localized specific absorption rate ("SAR") in Section 4.2 of "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992, Copyright 1992 by the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017. These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Section 17.4.5. Copyright NCRP, 1986, Bethesda, Maryland 20814."

[8] Foster et al., "Thermal response of tissues to millimeter waves: implications for setting exposure guidelines", Health Physics, December 2010.

almost entirely in the skin (within 1 – 2mm) and any temperature increase is also dissipated within the skin - no vital organs are exposed[9,10,11]. Foster et al.[12] point out that while a power density of 2000-3000 W/m^2 is estimated to increase the skin temperature of 10° C corresponding to the temperature threshold for thermal pain, the predicted skin temperature increase for a power density of 10 W/m^2 is only 0.05° C which is well below the 1° C used for the basic restrictions at lower frequencies.

Again, the age of the underlying recommendations and the state of scientific knowledge that was available at that time versus that known today, could well go towards explaining why the differences exist. That said, there appears to be no logical reason to maintain such outdated[13] limits when the scientific knowledge has advanced so far. It would indeed be ironic if the FCC requires the most advanced communications devices to be tested against the most outdated exposure limits.

The MMF has already recommended to the Commission in our filing in response to the RF Inquiry relating to the Commission's RF exposure rules and policies, that the IEEE C95.1-2005 provides a far better scientific basis for RF exposure limits. With the additional update provided by IEEE C95.1a-2010 this would ensure that the Commission's RF exposure limits applicable for higher

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[9] Khizhnyak EP and Ziskin MC Heating Patterns in Biological Tissue Phantoms Caused by Millimeter Wave Electromagnetic Irradiation. IEEE Trans Biomed Eng 41:865-873;1994
[10] Ryan KL etal Radiofrequency Radiation of Millimeter Wave Length: Potential Occupational Safety Issues Relating to Surface Heating. Health Phys 78:170-181;2000
[11] Alekseev SI and Ziskin MC Human Skin Permittivity Determined by Millimeter Wave Reflection Measurements. Bioelectromagnetics 28:331-339;2007
[12] Ibid.
[13] The original IEEE C95.1-1991 standard has been superseded twice in the intervening years (C95.1-1999 followed by C95.1-2005)

frequencies were based on the most up to date scientific knowledge. As a matter of fact, IEEE C95.1-2345 (2014)[14] was developed for military operation in NATO countries and was promulgated on November 26, 2015. This standard has the exact exposure limits as that of in the C95.1-2005, except some changes in induced and contact currents for 100 kHz -110 MHz, and a slight modification of exposure limit and associated averaging time for 100-300 GHz.

(B) Compliance related power reductions could create limitations in network coverage and capacity.

One issue of concern to the MMF and our members that are active in the development of 5G technologies is the maximum available output power that will be available from the user's device since this has a direct impact on network capacity and coverage. What can be seen is that under the current FCC limits at the transition frequency (6 GHz) where the exposure metric changes from SAR to PD, the maximum possible radiated power to meet compliance drops several dB and consequently the maximum output power is reduced to about 15 dBm or less[15]. While the work on 5G is still at an early stage, one recent conference paper[16] estimated that the discrepancy in the exposure limits above 6 GHz could reduce the achievable data rates to levels that may be inconsistent with current 5G performance expectations. Both Colombi et al.[17] and Wu et al.[18] point out that

[14] C95.1-2345 (2014) "IEEE Standard for Military Workplaces—Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz".
[15] D. Colombi, et al. Ibid..
[16] T. Wigren, D. Colombi, B. Thors, J.-E. Berg, *Implication of RF EMF Exposure Limitations on 5G Data Rates Above 6 GHz, accepted in 82th IEEE Vehicular Technology Conference, Sep. 2015 (to be published)*
[17] Ibid.
[18] T. Wu, T. S. Rappaport, C. M. Collins, "The Human Body and Millimeter-Wave Wireless Communication Systems: Interactions and Implications," accepted in 2015 IEEE International Conference on Communications (ICC), Jun. 2015.

under IEEE C95.1-2005, the discontinuity in the maximum transmit power is basically negligible.

As Wu et al. state: "(i)n other words, in order to comply with exposure limits at frequencies above 6 GHz, the maximum radiated power might have to be several dB lower than the power levels used for current mobile technologies. Since the available output power for user devices is critical on the system capacity and coverage, such an inconsistency is undesirable and should be addressed by relevant regulatory authorities to promote the development of future broadband mobile communication networks." The MMF wholeheartedly agrees and urges the Commission to address what will be a significant limitation on 5G devices and their networks.

(C) Greater clarity is required for manufacturers with regards to compliance testing methodologies

In order to be able to design 5G devices, manufacturers must be aware of the compliance testing framework in order to know the parameters that need to be met in order to demonstrate compliance prior to bringing a product to market. At present, one issue that is not at all clear is the limits for localized peak power density. FCC OET Bulletin No.65[19] states that "although the FCC did not explicitly adopt limits for peak power density, guidance on these types of exposure can be found in Section 4.4 of the ANSI/IEEE C95.1-1992 standard." Wu et al. point out that "the IEEE C95.1-1992 standard specifies relaxation of PD limits for exposure of all parts of the body except the eyes and the testes". For frequencies between 3

[19] Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Federal Communication Commission, OET Bulletin 65, Edition 97-01.

and 15 GHz, the averaging time is 90,000/f (where f is in MHz), and for frequencies between 15 and 300 GHz, the appropriate averaging time is 616,000/f minutes (where f is in MHz). For occupational/controlled exposures, the peak power density should not exceed 200(f/6) W/m^2 at frequencies between 6 and 96 GHz (where f is in GHz), and 400 W/m^2 at frequencies between 96 and 300 GHz. For general population/uncontrolled exposures, the peak PD should not exceed 10(f/1.5) W/m^2 for frequencies between 6 and 30 GHz (f is in GHz), and 200 W/m^2 at frequencies between 30 and 300 GHz.

Wu et al. also point out that "(w)hile the FCC has not updated the statements regarding limits on peak power density for localized exposure scenarios issued about 20 years ago, the ANSI/IEEE C95.1 standard has been modified with the evolution of technology. In the ANSI/IEEE C95.1-2006 standard, relaxation of the PD MPEs is allowed for localized exposures on any part of the body. The PD are intended to be spatially averaged over an area of $100\lambda^2$ for frequencies below 30 GHz (λ is in cm), and averaged over 100 cm^2 for frequencies above 30 GHz. The averaging time is 6 minutes for occupational/controlled exposures, and 30 minutes for general population/uncontrolled exposures. For exposures in controlled environments, the spatial peak value of the PD shall not exceed 200(f/3) W/m^2 at frequencies between 3 and 96 GHz (f is in GHz), and 400 W/m^2 at frequencies from 30 GHz to 300 GHz. For exposures in uncontrolled environments, the spatial peak value of the PD shall not exceed $18.56(f)^{0.699}$ W/m^2 at frequencies between 3 and 30 GHz (f is in GHz), and 200 W/m^2 at

frequencies from 30 GHz to 300 GHz."

Manufacturers would therefore welcome guidance from the Commission as to whether the measurement and assessment issues raised by Wu et al.[20] including the spatial and time averaging could be, for example, dealt with via the KDB process rather than through the NOI procedure. The MMF believes that as these are measurement/assessment issues, they fall squarely within the remit of the existing KDB process.

III - CONCLUSION

The interest in the utilization of frequency bands above 6 GHz for future radio communication systems is increasing and the MMF has indicated in this submission that it supports the Commission's proposals to allow the use of these higher frequency bands for radio communication systems particularly in relation to 5th generation ('5G') networks and devices. The MMF therefore encourages the Commission to continue to proceed with the current rule making addressing the spectrum related issues.

The use of these frequencies brings new challenges in terms of EMF exposure assessment and measurement. The MMF has demonstrated that there are differences between the ICNIRP, IEEE and FCC RF exposure limits in this area, particularly the point at which the exposure limits change from SAR in the body to power density in air. The better basis for the limits in the range under

[20] Ibid.

consideration would be those from IEEE C95.1-2005 and C95.1a-2010. The differences though also raise issues for device design particularly the findings that for a device used in close proximity to the body at the transition frequency where the exposure metric changes from SAR to PD, compliance with current FCC EMF exposure limits would see a discontinuity of several dB such that the estimated maximum output power in uplink for such devices would be much lower compared to what used today below 6 GHz. The impact this discontinuity would have on network capacity and coverage would be significant and would limit some of the benefits that 5G promises let alone the unnecessary cost implications that would necessarily follow particularly for network roll-out. While we have raised these issues concerning the discontinuity in the exposure limits we do agree with the Commission[21] that the issue is better dealt with in the context of the RF Inquiry.

The MMF has also highlighted the importance for manufacturers of receiving greater clarity from the Commission as to the measurement and assessment methodologies that are to be used for demonstrating compliance at these higher frequencies, and in particular whether these issues could be dealt with via the existing KDB process. Early guidance on these issues is essential for manufacturers in order to incorporate the relevant factors into product design and to establish compliance of these products in order to bring them to market in a timely and cost effective manner.

The MMF wishes to thank the FCC for its consultation and the opportunity to

[21] Id. at Paragraph 321

provide our views on these important issues.

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